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# A Test of Two Theories of the Necker Cube Reversal Illusion

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A TEST OF TWO THEORIES OF THE  
NECKER CUBE REVERSAL ILLUSION

BY

PHILLIP POWERS WOODSON, JR.

A THESIS  
SUBMITTED TO THE GRADUATE FACULTY  
OF THE UNIVERSITY OF RICHMOND  
IN CANDIDACY  
FOR THE DEGREE OF  
MASTER OF ARTS  
IN PSYCHOLOGY

MAY 1979

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Abstract

The Necker cube reversal illusion was used to test the satiation and constructional theories of this illusion in an experimental paradigm. The paradigm involved one group of 51 university students who were tested under three experimental conditions. All three test sessions involved their watching a Necker cube for a continuous 2 minute period.

Each session was separated by at least a 1 day interval. One session involved the plain cube. Another session involved a fixation mark in the center of the cube and a third session had the mark sequentially appearing in four different locations in the central region of the cube. The subject was instructed to gaze into the cube, fixate on the fixation mark, and to sequentially fixate on the mark wherever it appeared in the respective aforementioned conditions.

Based on pilot research, it was expected that the no fixation mark condition would yield a significantly lower number of reversals than the one fixation mark and be significantly above the sequential fixation condition which should have had the lowest mean, thus reflecting the increasing degree of disruption of the satiation mechanism.

This would have supported a satiation as opposed to a cognitive, constructional mechanism of the Necker cube reversal phenomenon under these conditions. The obtained data failed to replicate the earlier findings on this point.

It was concluded that this experimental manipulation has insufficient power to adequately test the two theories.

## A Test of Two Theories of the Necker Cube Reversal Illusion

Two theories have been put forth to explain the Necker cube reversal illusion. One involves the concept of satiation of orientation, the other postulates the operation of a cognitive, perceptual mechanism which constructs the two alternate orientations of cube perspective.

Kohler (1940, 1947) and Kohler and Wallach (1944) introduced the satiation theory of ambiguous figure reversals. Reversals are thought to be due to an innate, neurophysiological mechanism of neuronal fatigue or satiation due to electrolytic resistance build up and the tendency of the brain, as an organ system, to expend energy in the most economical manner. In the case of the Necker cube, the retinal image projects the cube contours into the visual cortex where they are embedded in an electrolytic medium of direct current flow. The electrolytic medium is altered by the cortical projection in that electrolytic resistance builds up in the current direction flow around the cortical cube projection. Hence, this cortical projection requires increasingly more energy to maintain itself as electrolytic resistance increases. Thus it becomes more and more economical for the cortical projection to modify its pattern in a less resistant fashion. When it does, we experience the reversal of the Necker cube.

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We give special thanks to Terry Goldman, Edward J. DeLong, and Sue Bass of the Learning Resources Center of the University of Richmond for their kind assistance in filming and for providing experimental space, projection, and sound equipment.

This theoretical mechanism of ambiguous figure reversal has much support. For example Hochberg (1950) and Carlson (1953), using an ambiguous figure illusion, had subjects preview during a pre-test period one of the two possible alternate orientations of an ambiguous figure which was shown during a test period immediately following the pre-test period. They found that more subjects began the test period by perceiving the other, nonpreviewed alternative which was also seen for longer periods of time during the test period than the other orientation which was previewed during the pre-test period. Apparently, the alternative viewed during the pre-test period satiated the visual system enough so that when the ambiguous figure was presented during the test period, the other previously nonsatiated alternative was perceived first and for longer periods of time.

Also, Brown (1955) and Cohen (1959) have shown that the rate of reversal increases over time until reaching an asymptotic rate when an ambiguous figure illusion is viewed continuously. Satiation apparently builds up over time, as the image conduction continues, and thus mediates more reversals per unit time until an asymptotic rate is reached. This increasing rate of reversal over time is considerably reduced if the exposures are separated by intervals (Orbach, Ehrlich, and Heath, 1963) or if rest periods are introduced (Spitz and Lipman, 1962). Therefore, the satiation build up is apparently disrupted if the image conduction is interrupted.

An alternate, cognitive theory developed by Rock (1975, 1976) contends that a constructional, interpretational process mediates

the ambiguous figure reversal illusion. Rock (1975, 1976) contends that, with the Necker cube illusion, a constancy mode constructs the two-dimensional, proximal mode input into the three-dimensional perception of a cube in one orientation. The constancy mode then reorganizes this construction into a cube of the alternate orientation. This cognitive reorganization causes the Necker cube reversal illusion. The constancy mode "knows", on the basis of past experience and innate knowledge, that both orientations could be veridical representations of the distal reality and thus the constancy mode constructs the proximal image first one, then the other way.

Cohen (1959) concluded that inspection of pre-test cubes differing only in size from the test cube can induce an increase in the rate of apparent change of the test figure even when pre-test and test figure contours do not coincide. Although the rate increase is not as marked as that produced by observation of the identical figure during pre-test and test periods, this would seem to support a cognitive interpretational model of ambiguous figure reversal. That is, the replacement of the pre-test cube with a larger or a smaller test cube did not drastically disrupt the mediational mechanism's operation rate. A satiation mechanism should have been markedly disrupted by such a manipulation.

Previous research by Spitz and Lipman (1962) found a no fixation mark viewing group to perform at the same level as a fixation mark viewing group. They used a continuous 2 minute viewing condition of the Necker cube for both conditions.

According to satiation theory, the use of a fixation mark should result in a more rapid induction of satiation than when no fixation mark is used, since there should be fewer eye movements and more repetitive stimulation to particular cortical areas, and thus the fixation group should have had significantly more reversals during the 2 minute viewing period than the no fixation group. Rock (1975) uses the Spitz and Lipman (1962) findings to support a cognitive interpretative mechanism which he believes may mediate Necker cube reversal illusions since a fixation mark should increase the effectiveness of a satiation mechanism if, indeed, one is operative.

Perhaps Spitz and Lipman (1962) failed to find support for the satiation theory on this point because of insufficient power in the independent groups design which they used for the fixation and no fixation conditions.

The present experiment was designed to reduce error variance and increase power by the use of a repeated measures design. The experimental hypothesis predicted that a significantly higher number of Necker cube reversals would be reported in the fixation as opposed to the no fixation condition. A third experimental condition, involving a fixation mark which sequentially appeared in different locations within the cube, was included in the present experiment to systematically change the retinal and cortical locations of the isomorphic representation of the cube within the brain. This manipulation was predicted to yield a significantly lower mean number of reversals than the no fixation mark condition since this sequential fixation condition should have the greatest and most

efficient disruption on the satiation process. The experimental hypothesis was based on past pilot research which showed the mean amount of reversals reported during a 2 minute viewing period of the Necker cube to be significantly higher with a fixation than with a no fixation mark condition in a repeated measures design.

If the present studie's experimental hypothesis were confirmed, the satiation theory would be supported. If non-significant differences were found between all three conditions this would not refute the cognitive, constructional theory since the experimental manipulations would have no effect on the rate of perceptual construction between the two alternate percepts.

#### Method

Subjects. Fifty-one subjects participated in this experiment in order to fulfill a class requirement in introductory psychology at the University of Richmond. All subjects had seen in class a movie on optical illusions (Lazarus, 1971) which demonstrated various illusions, including the Necker cube, so that they would be familiar with this optical illusion. A few weeks after the movie, in subject recruiting, a brief historical introduction and demonstration of the Necker cube reversal illusion was also given in class.

Apparatus. All three experimental conditions involved a Necker cube which was projected onto a 10 inch (25.4 cm) tall by 11 inch (27.94 cm) wide white screen via an 8 mm motion picture projector set at 24 frames per second so that a cube with a 4 inch (10.16 cm) square front and back with 2 inch (5.08 cm) long sides appeared in the center of the screen.

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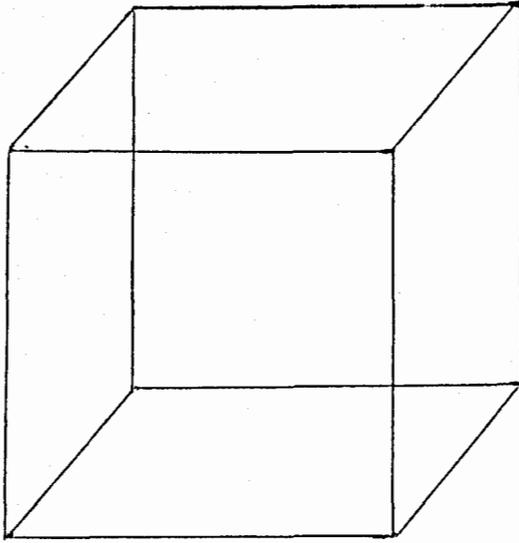
Insert Figure 1 about here

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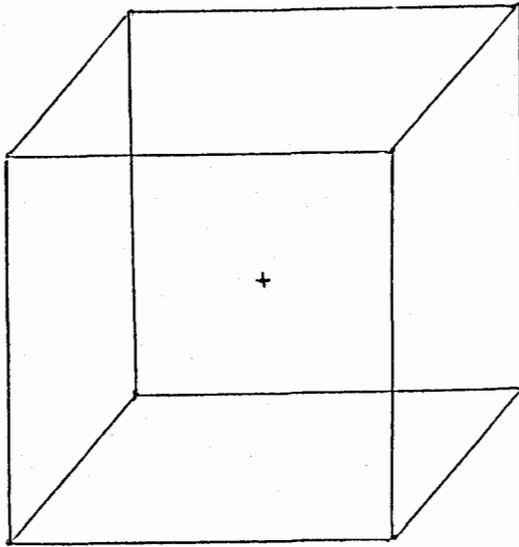
In the no fixation mark condition the Necker cube was presented as in Figure 1A. The cube had a small cross in its center in the fixation mark condition as shown in Figure 1B. And in the sequential fixation mark condition the cube had four small fixation marks in the central region, all being  $\frac{1}{2}$  inch (1.27 cm) off center and located on the vertical and horizontal axes of the cube as shown in Figure 1C. These marks appeared one at a time during the viewing session. The upper cross appeared for the first 30 seconds, the lower cross for the second 30 seconds, the left cross for the third 30 seconds, and the right cross for the fourth 30 seconds.

Recorded instructions were presented via a tape recorder for each condition. Each subject recorded the number of reversals experienced in each condition with a hand counter.

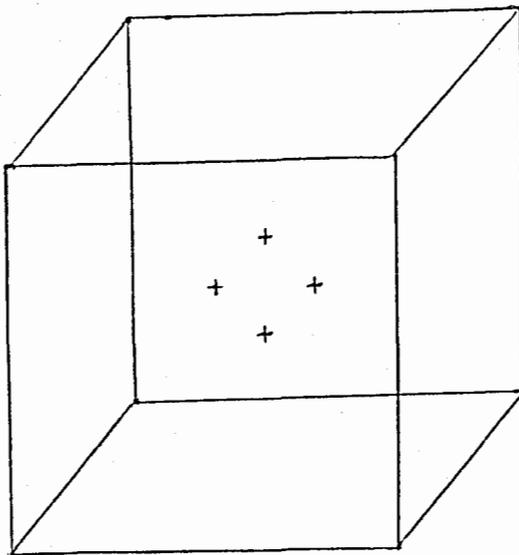
Procedure. In all three experimental conditions the subjects were seated in front of the experimenter at a table in a quiet, dimly lit room. Subjects were tested individually with each of the three sessions being at least 24 hours apart. The three sessions for each subject were also scheduled at the same time of day to avoid any possible confounding diurnal cycles that could effect the rate of cube reversal. The white viewing screen was 46 cm from the nasion of the subject with the nasion intersecting the central axis of the screen approximately at right angles. Subjects were asked to wear their corrective lenses during all three test phases if they had corrected vision. The sequence of the three phases was counterbalanced across subjects. In all three conditions the test period was prefaced by



A



B



C

Figure 1. A) Necker cube without fixation mark, B) Necker cube with fixation mark, and C) Necker cube with the four sequentially appearing fixation marks.

a tape recorded explanation (see Appendix A, sections 1-3) that the Necker cube is a figure reversal illusion and that the cube would seem to flip back and forth between two different orientations or perspectives as they watched it during a continuous 2 minute period. They were asked to assume a passive attitude to the illusion by letting the reversals happen to them and not trying to make it change since it would change in perspective without their help. When the cube changed to the alternate orientation the subject would record this change by pressing the button on the hand counter and when it changed back to the original orientation the subject would again press the hand counter button. The total number of reversals counted was recorded at the end of each test session.

Immediately prior to each test session, a 1 minute adaptation period involved the subject gazing into the blank white screen. After this standard adaptation period, the test cube appeared for a continuous 2 minute period. At the end of each test session the subject was asked to describe the change in perspective to ensure that the subject was indeed experiencing and recording the reversal illusion (see Appendix A, section 4).

In the no fixation mark condition the subject was asked to gaze into the midst of the cube and yet to be aware of the cube as a whole so as to be aware when the cube changed in perspective. In the fixation mark condition, the subject was asked to focus his or her eyes on the cross in the center of the cube during the entire 2 minute period and yet to still be aware of the cube as a whole. And in the sequential fixation mark condition, the subject was instructed to focus on the cross wherever it appeared. The subject did not know

the aforementioned pattern sequence of cross appearance in this condition but did know that the cross would appear in four different locations within the central region of the cube. Here too, the subject was instructed to also be aware of the entire cube while focusing on each mark. In all three conditions the subject was also asked to keep head movements to a minimum and not to record the vanishing line illusion where the lines of the cube seemed to disappear or fade in and out of view. For the verbatim instructions played on the tape recorder for each condition see Appendix A, sections 1-3.

### Results

An initial Latin Square analysis yielded Group, Interaction, and Order factors non-significant at the .05 level. This allowed the pooling of like viewing conditions across groups. With like conditions pooled, a Single Factor, Repeated Measures Analysis of Variance was then applied (see Table 1).

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Insert Table 1 about here

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The obtained  $F$  was significant at the .05 level. A Newman-Keuls analysis was then applied to describe the specific differences between the three means. The only significant difference, at the .05 level, was between the no fixation and sequential fixation viewing condition means with the former being higher than the latter (see Table 2).

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Insert Table 2 about here

---

Pearson product moment correlation coefficients between the

Table 1

## Single Factor, Repeated Measures ANOVA Summary Table

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Between	50			
S	50	27814.61	556.29	
Within	102			
T	2	313.97	156.99	3.3141*
T X S	100	4736.81	47.37	
Total	152	32865.39		

\* $p < .05$ .

Table 2

Newman-Keuls Test Summary Matrix

Viewing Conditions ↓	→		
	Sequential Fixation	Fixation	No Fixation
	Sample means		
	25.78	27.22	29.28
	Differences between sample means		
Sequential Fixation	0.00	1.44	3.50*
Fixation		0.00	2.06
No Fixation			0.00

\*p < .05.

three viewing conditions, for the number of reversals reported for each subject in each condition, were significant at the .05 level. The coefficient between the no fixation and fixation condition being +.76, between the no fixation and sequential fixation condition +.83, and between the fixation and sequential fixation condition +.76.

### Discussion

The results of the present research do not support the satiation theory since the experimental hypothesis was not supported. Nor do they replicate the significant difference between viewing condition means found in the pilot research.

These findings are inconclusive in regard to the cognitive, constructional theory since this theory would hypothesize non-significance between all three conditions.

The +.76 Pearson correlation coefficient obtained in the pilot work was replicated in the present study. Therefore, the mechanism mediating the Necker cube reversal illusion operates at a fairly constant rate for each individual across the different viewing conditions whether they are separated by a 1 day or 1 month interval. Large intersubject differences in rate may also be inferred from these significant correlation coefficients.

In the pilot experimentation, 51 subjects were randomly selected from the University of Richmond student body. They were first given the no fixation mark condition session then, 1 month later, they had the fixation mark condition. Both sessions involved a continuous 2 minute viewing period of the Necker cube with most of the experimental parameters being the same except that

the cubes were drawn on paper and regarded on a table in the pilot experiment whereas they were presented via film and regarded on a screen directly in front of the subject in the present experiment.

Since studies (Spitz and Lipman, 1962; the author's pilot and present work) which have used the fixation mark manipulations have obtained conflicting results which are also at variance with the preponderance of research cited, perhaps this means of testing the satiation against the constructional theory of the Necker cube reversal illusion is insufficiently powerful so as to reveal the satiation process at work. And too, perhaps more is involved in this illusion than satiation. That is, perhaps a cognitive constructional mechanism is also operative.

## Appendix A

1.) No fixation mark condition:

I want you to gaze into the blank white screen that will appear in front of you. After 1 minute of blankness, a three-dimensional cube will appear on the screen for a 2 minute period after which this session will be over.

I want you to gaze into the midst of this three-dimensional cube you will see and yet still be aware of the cube as a whole. You should do this for the entire 2 minute period. You will recognize it as one of the optical illusions you saw in the movie I showed you earlier and as the figure I drew on the board during the introduction to it which I gave during the recruitment of subjects. As you know from the introduction, this cube will appear to flip back and forth between two seemingly different perspectives or orientations of position. Each time you see the cube change in perspective, press the button on the hand counter I will give you. When it changes from one perspective to the other record this change by pressing the hand counter button and when it changes back to the original position again press the button. Then, when it changes back to the alternate orientation press the button again. Therefore, you should press the button each time it changes, regardless of which of the orientations it has changed to.

The reason I also want you to be aware of the cube as a whole is so that you will be aware when the cube changes in perspective so that you can record the change.

Also, please do not count the reversals in your mind, only

press the hand counter button which will do the counting for you.

And too, please try to keep head movements to a minimum while viewing the cube.

You may also notice another illusion where the lines of the cube seem to disappear momentarily or fade in and out of view. Please do not record this illusion of the vanishing lines for I am only interested in the perspective reversal illusion.

Remember too, to maintain a passive attitude toward the reversal illusion. That is, do not try to make the cube change in perspective, just let it happen to you and experience it since it will change in perspective without you having to make it change.

If you have any questions please ask the experimenter who is with you.

## 2.) Fixation mark condition:

I want you to gaze into the blank white screen that will appear in front of you. After 1 minute of blankness, a three-dimensional cube will appear on the screen for a 2 minute period after which this session will be over.

I want you to focus your eyes on a small cross in the center of this three-dimensional cube you will see and yet still be aware of the cube as a whole. You should do this for the entire 2 minute period. You will recognize it as one of the optical illusions you saw in the movie I showed you earlier and as the figure I drew on the board during the introduction to it which I gave during the recruitment of subjects. As you know from the introduction, this cube will appear to flip back and forth between two seemingly

different perspectives or orientations of position. Each time you see the cube change in perspective, press the button on the hand counter I will give you. When it changes from one perspective to the other record this change by pressing the hand counter button and when it changes back to the original position again press the button. Then, when it changes back to the alternate orientation press the button again. Therefore, you should press the button each time it changes, regardless of which of the orientations it has changed to.

The reason I also want you to be aware of the cube as a whole is so that you will be aware when the cube changes in perspective so that you can record the change.

Also, please do not count the reversals in your mind, only press the hand counter button which will do the counting for you.

And too, please try to keep head movements to a minimum while viewing the cube.

You may also notice another illusion where the lines of the cube seem to disappear momentarily or fade in and out of view. Please do not record this illusion of the vanishing lines for I am only interested in the perspective reversal illusion.

Remember too, to maintain a passive attitude toward the reversal illusion. That is, do not try to make the cube change in perspective, just let it happen to you and experience it since it will change in perspective without you having to make it change.

If you have any questions please ask the experimenter who is with you.

3.) Sequential fixation mark condition:

I want you to gaze into the blank white screen that will appear in front of you. After 1 minute of blankness, a three-dimensional cube will appear on the screen for a 2 minute period after which this session will be over.

I want you to focus your eyes on a small cross that will appear in the middle region of this three-dimensional cube you will see and yet still be aware of the cube as a whole. You should do this for the entire 2 minute period. The cross will appear in four different locations within the central region of the cube. Each time it changes its location you should refocus your eyes on the cross in its new location so that your eyes are always focused on the cross no matter where it is located within the cube. You will recognize it as one of the optical illusions you saw in the movie I showed you earlier and as the figure I drew on the board during the introduction to it which I gave during the recruitment of subjects. As you know from the introduction, this cube will appear to flip back and forth between two seemingly different perspectives or orientations of position. Each time you see the cube change in perspective, press the button on the hand counter I will give you. When it changes from one perspective to the other record this change by pressing the hand counter button and when it changes back to the original position again press the button. Then, when it changes back to the alternate orientation press the button again. Therefore, you should press the button each time it changes, regardless of which of the orientations it has changed to.

The reason I also want you to be aware of the cube as a whole

is so that you will be aware when the cube changes in perspective so that you can record the change.

Also, please do not count the reversals in your mind, only press the hand counter button which will do the counting for you.

And too, please try to keep head movements to a minimum while viewing the cube.

You may also notice another illusion where the lines of the cube seem to disappear momentarily or fade in and out of view. Please do not record this illusion of the vanishing lines for I am only interested in the perspective reversal illusion.

Remember too, to maintain a passive attitude toward the reversal illusion. That is, do not try to make the cube change in perspective, just let it happen to you and experience it since it will change in perspective without you having to make it change.

If you have any questions please ask the experimenter who is with you.

#### 4.) Description by subject of Necker cube illusion:

After each session the subject was asked to describe the change in perspective to ensure that he or she had indeed experienced the Necker cube reversal illusion.

If they said, "It seemed to come out of the screen and then to go back in" or "It seemed to be like a cube lying on a table and then it seemed like a cube being held up in the air", the subjects' records were probably valid.

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## Vita

Personal

Born: 3/25/52; Richmond, Virginia

Marital status: Single

Draft status: 1H as of 3/1/72

Address: Phillip P. Woodson, Jr.

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Parents (same address as above):

Phillip P. Woodson, Sr. Medical College of Virginia

Dorothy H. Woodson Virginia Employment Commission

Previous Employment

Duration	Position	Hours	Firm
7/73-8/73	Laborer	Full Time	Dept. of Parks, City of Richmond

Duties: Maintenance and flood restoration of James River City Park.

6/74-8/74	Counselor	Full Time	Camp Hanover Education Center
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Responsible day and night for 6 boys at a summer camp. Worked with female co-counselor responsible for 6 girls. Led out-of-door activities.

2/75-7/76	Child Care Worker	Full and Part Time	Commonwealth Psychiatric Center
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Milieu therapist for children and adolescents with emotional and/or mental disorders.

Education

School	Name	Location	Duration	Time
Kindergarten	Brook Hill	Richmond, Va.	2 yrs.	1957-59
Elementary	Ginter Park	" "	5 yrs.	1959-64
Junior High	Chandler	" "	2 yrs.	1964-66
High School	John Marshall & Thomas Jefferson	" "	3 yrs. 1 yr.	1966-69 1969-70
University	Virginia Common- wealth Univ.	" "	4½ yrs.	1970-74
Graduate School	Univ. of Richmond	" "	3 yrs.	1976-79

Academic Honors and Awards

Graduated from Virginia Commonwealth University with honors (upper 10% of graduating class).

Member of Psi Chi honor society (Psychology).

Graduate School Assistantship Duties

Physiological psychology laboratory assistant (Univ. of Richmond). Assisted with laboratory instruction.

Research assistant (Univ. of Richmond). Worked on ongoing research.

Research Experience

1. Investigation of incidental learning and creativity (Virginia Commonwealth University).
2. Electroencephalographic work with the Average Evoked Potential as an indice of C.N.S. stimulus intensity modulation level. (Medical College of Virginia and University of Richmond).
3. Shock elicited aggression, psychogenetics, and nicotine (Institut f. Verhaltenswissenschaft, E.T.H.).
4. Nicotine in humans and the Average Evoked Potential (Medical College of Virginia and Virginia Commonwealth University).

Papers

Driscoll, P., Woodson, P., & Battig, K. Shock-induced fighting differences in 2 rat strains and injections of a "smoking dose" of nicotine. Abstract presented as a poster demonstration at the Seventh International Congress of Pharmacology IUPHAR on July 16-21, 1978 in Paris, France. Abstract available from:

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Driscoll, P., Woodson, P., & Battig, K. Shock-induced fighting differences in Roman High- and Low- Avoidance rats. Abstract presented as a poster demonstration at the Tenth Annual Reunion of the USGEB on May 19-20, 1978 in Davos, Switzerland. This abstract submitted for publication in Experientia, 1978.

Woodson, P. P. & Tromater, L. J. A test of two theories of the Necker cube reversal illusion. Abstract presented as an oral presentation at the Southern Society for Philosophy and Psychology convention on April 12, 1979 in Norfolk, Virginia.

Languages

Three years of oral and written French (High School).

One year of written scientific German (University).